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Agriculture Land Suitability Analysis using AHP and GIS: A Case Study of Chamarajanagar Taluk of Chamarajanagar District, KA.

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Abstract:

Land-use suitability refers to how well a particular type of land can accommodate a specific purpose. This assessment involves analyzing various factors, including not only the natural characteristics of the land but also its socioeconomic and environmental impacts. Conducted within a Geographic Information System (GIS) framework, this assessment becomes a multi-criteria decision-making (MCDM) challenge. In the Chamarajanagar taluk of Chamarajanagar district, we conducted a study to assess the suitability of the area for agricultural purposes. Employing a hybrid approach combining the analytic hierarchy process (AHP) and GIS methodologies, we evaluated land suitability based on a range of criteria and sub-criteria. Our findings revealed that 19.44% of the study area exhibited high suitability, 66.97% showed medium suitability, and 13.59% demonstrated low suitability for agriculture. Overall, the lands in Chamarajanagar exhibit a medium potential for agricultural use. Our research utilized a combination of qualitative and quantitative techniques to arrive at these conclusions.

Keywords: Agriculture, Land suitability, AHP, GIS, Chamarajanagar

1. Introduction:

Land, constituting a portion of the Earth's surface, exhibits relatively stable or predictable cyclic activity. Its suitability for agriculture, settlement, and industrial purposes (Akinci et al., 2013) hinges on various factors. However, these factors have experienced depletion, particularly over the past few centuries. Consequently, numerous lands grapple with issues such as soil erosion, waterlogging, groundwater depletion, excessive runoff, and diminished productivity (Bagheri et al., 2012) (Özkan et al., 2020) jeopardizing the quality and accessibility of food, water, and energy and impinging upon the security and quality of life for approximately 250 million people, adversely impacting the lives of a billion others. For instance, the FAO has documented that 852 million individuals in the developing world suffer from hunger and malnutrition(Cengiz & Akbulak, 2009). Moreover, land resources are dwindling as burgeoning populations exert pressure on natural resources. With the global population expanding, an urgent need arises for increased food production. Furthermore, land use policies in developing nations often utilize available technical information, and when utilized, policymakers often require concise interpretations devoid of technical intricacies (Feizizadeh et al., 2014). Land suitability assessment resembles the process of selecting suitable locations for land use and seeks to delineate a suitability index across the entire study area. Choosing the most fitting algorithm for land suitability assessment holds significance for both current and future land use planning endeavors (Jafari & Zaredar, 2010).

The development of suitability maps stands as a critical prerequisite for making informed land-use decisions. Numerous parameters and criteria regarding land and its potential uses must be carefully considered. While biophysical and environmental factors tend to be less susceptible to human influence, social and economic factors are often subject to manipulation through human interventions (Armanios & Fisher, 2014). Thus, determining the relative importance or weight of each factor influencing land suitability constitutes a pivotal step in assessing land suitability for crop production. Assigning weights to these factors can be challenging due to their varying degrees of significance to the stakeholders involved. To address this complex and multi-dimensional issue, multi-criteria techniques are employed. A range of multi-criteria evaluation methods exists. Mc Harg and Mumford introduced a planning methodology for systematic land use by incorporating the concept of compatibility among multiple land uses. They noted the variability of factors affecting land and their relative values, making optimization for a specific single use challenging. However, they proposed optimizing land use for multiple, compatible uses and introduced a straightforward matrix system to assess the degree of compatibility. In recent years, there has been an expansion in the combined use of multi-criteria decision-making (MCDM) and Geographic Information Systems (GIS). This integration has enhanced land evaluation processes, decision-making, and the efficiency of data processing (Mendas & Delali, 2012).

The Analytic Hierarchy Process (AHP), as elucidated by (Taherdoost, n.d.), serves as a decision support tool tailored to address intricate decision-making challenges. This method employs a multi-level hierarchical framework encompassing objectives, criteria, sub-criteria, and alternative options. Interest in multi-criteria assessment within agriculture, environmental studies, and rural management has surged due to its promising potential A. A. Mustafa1 (2011). Furthermore, it aids in refining the characterization of land utilization types essential for land evaluation(Memarbashi et al., 2017), offering a robust spatial decision support system facilitating the creation of precise land suitability maps. The amalgamation of AHP with Geographic Information Systems (GIS) represents a burgeoning trend in land suitability analysis (Ennaji et al., 2018), with prior research integrating multi-criteria decision-making (MCDM) techniques, particularly AHP, with GIS. For instance, Gemitzi, Tsihrintzis, and Petalas utilized these methods to address environmental issues. (Khan & Ahmed, 2023) combined both techniques to identify potential sites for soil and water conservation practices in Northern Peru's Ronquilo watershed. Similarly, (Rondhi et al., 2018) and (Kumar Prajapati et al., 2015) integrated GIS with MCDM to locate water harvesting ponds in Northern Jordan. Their analysis incorporated 20 factors as suitability parameters, encompassing climatic conditions, soil characteristics, nutrient composition, and topographical data.

2. Materials and methods:

2.1 Study area:

Geographically, Chamarajanagar is in the southern region of the Deccan Peninsula, positioned between latitudes 11°30'N and 12°15'N, and longitudes 76°30'E and 77°45'E. Its elevation stands at 708.66 meters above mean sea level. Chamarajanagar Taluk occupies a total area of 1210 sq.km, and the forest area covered 260 sq.km. Taluk has 5 hoblis and 184 villages. The population of this taluk is 3,57,799 as per the 2011 census of India. Which 1,78,555 are males and 1,79 244 are females.

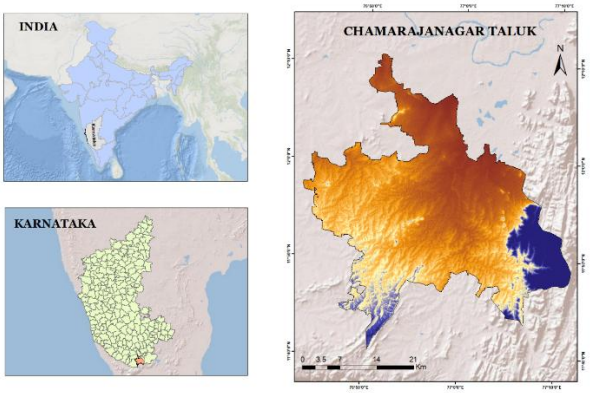

Figure 1: Location map of the study area

2.2 Database and Methodology:

The methodology employed in this study is illustrated in Fig. 2. To conduct the analysis of agricultural land suitability, a diverse range of satellite images and conventional datasets were collected from government agencies and online sources. A Digital Elevation Model (DEM) with a resolution of 15 meters was obtained from the official website of the ALOS PALSAR. This DEM was processed using ArcGIS 10.7.1 software to delineate the preparation of the relief, slope, and maps. Additionally, the drainage density map was generated using hydrology tools within ArcGIS.
The geological and geomorphological maps have been taken from the Geological Survey of India, and Landsat 8 images of the study area have been collected from the United States Geological Survey (USGS) official website (https://earthexplorer.usgs.gov) and handled in ERDAS Imagine software to create the Land use and land cover classification map. The soil texture map has been taken from the National Bureau of Soil Survey (NBSS). The rainfall map has been collected from TRMM NASA after generating the thematic maps, and all the thematic maps have been converted to raster format with 90 m spatial resolution. After that, by simultaneously applying the analytical hierarchy process (AHP) ranks to the land suitability, which involves 8 susceptibility criteria, the land suitability map is generated.

2.3 Data processing and analysis:

In this study area, a flowchart methodology was devised for suitability analysis, which involved generating several spatial maps, including slope, relief, stream density, geology, geomorphology, soil texture, rainfall, land use, and land cover. These datasets were sourced from various references, comprising 8 parameters in total. Utilizing spatial analysis tools, the data were converted to raster format, reclassified, and assigned weights and rankings based on their importance and significance. The Analytic Hierarchy Process (AHP) method was employed with ArcGIS 10.7.1 software to facilitate this process. Subsequently, a map depicting the suitability of land for agriculture was produced.

Fig 2: Methodology flow chart developed for agricultural land suitability

2.4 Preparation of Thematic Maps

1. **Relief**

The higher relief and slope values are seen in the south-eastern part of the area. and the lower height is found in the core part of Chamarajanagar taluk, less than 400 meters, and the area of higher relief has been found in the southeast part of the study area, more than 1200 meters respectively.

2. **Rainfall**

The rainfall map was generated by TRMM-NASA (1961-2018). The annual average rainfall in this area ranges between 600 and 1200 millimeters. The rainfall decreases towards the North-east in the range of

average precipitation of less than 600 millimeters, and the northwest part results show high rainfall of more than 1000 millimeters in the study area.

3. Soil texture

Understanding the soil texture is a crucial aspect of assessing agricultural land suitability. It is essential to examine the soil types present in a specific area. In this particular region, the predominant soil type is loamy soil. However, loamy and clayey soils are observed in the northeast and northwest sectors of the study area, while sandy soil predominates in the northeast, and a small area is found in rockland.

4. Geology

Most of this area is covered by peninsular gneiss. The migmatites and chanockites are the primary forms of rock that dominate the small stretch of plain land in this taluk. This study area has three types: charnockites, migmatite gneiss, and peninsular gneiss.

5. Geomorphology

The taluk can be broadly classified into plains, undulating terrain, and partially elevated regions resembling tablelands and mountains. Pediment zones feature gently sloping surfaces of eroded bedrocks nestled between hills and plains, primarily composed of granodiorite and migmatitic gneisses. These landforms result from the extensive weathering of granitoids. The landscape encompasses hills, the southeastern Ghats, undulating tablelands, lofty mountains, and forested areas. The various landforms are observed in this study area. Such as pediplain, structural hills and valleys, and denudational hills.

6. Slope

Slope plays a significant role in the analysis of agricultural land suitability. To assess slope characteristics, a slope map was created using Digital Elevation Model (DEM) data with a spatial resolution of 12.5 meters, obtained from the ALOS PALSAR. The slope map was generated utilizing the slope function within the spatial analysis toolbox of ArcGIS 10.7.1 software. Slope degree, measured in degrees, is a critical factor in erosion control. Areas with slopes ranging from 0 to 3 degrees are considered flat and conducive to agricultural production. Conversely, slopes in the range of 35 to 50 degrees denote steep terrain with high surface runoff, rendering them unsuitable for agriculture. The study area primarily consists of flat terrain in the core part with varying degrees of slope ranging from moderate to very steep.

7. Drainage density

The taluk has a good drainage system and falls in the Cauvery River basin. There are no major rivers in the Chamarajanagar taluk of Chamarajanagar district. Suvarnavathy rises near Gajjalahalli in the southeastern middle of Chamarajanagar taluk and flows north-south through Chamarajanagar and Yelandur taluks before joining the Cauvery River. If the density is low, the result is good for agricultural activities. There is a wide subsurface where the drainage potential is high, if the density is high. The region has five classes of drainage density. Very low density is (< 0.81) and very high density is (>3.26) in the study area.

8. Land use and Land cover

The land use and land cover map was prepared from Landsat-8 (USGS) data. The classes are extracted using ArcGIS 10.7.1 software. The study area is divided into 7 classes, namely agricultural land, barren rocky, built-up, forest, forest scrub, barren scrubland, and water bodies. The forest land covers about 18.87% (228.32 sq km) (District factbook) in the south-east. The land use and land cover map was shown in (Fig.10)

Table 1: classification of land use and land cover

S.N.	Classes	Area (Sqkm)	Percentage
1	Barren Rocky	1.17	0.097
2	Waterbodies	18.01	1.489
3	Forest Scrub	6.07	0.502
4	Barren Scrubland	53.03	4.383
5	Agriculture	863.83	71.39
6	Forest	222.25	18.368
7	Built-up Land	45.69	3.776
	Total	**1210**	**100**

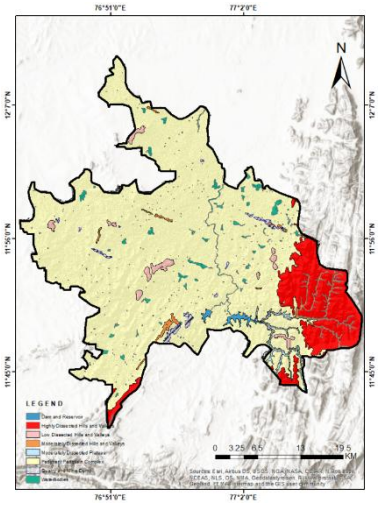

Figure 3: Geomorphology map

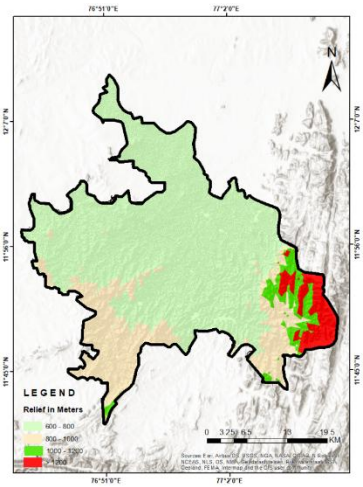

Figure 4: Relief map

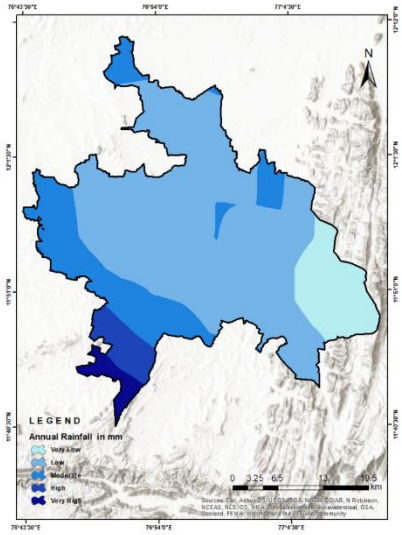

Figure 5: Rainfall map

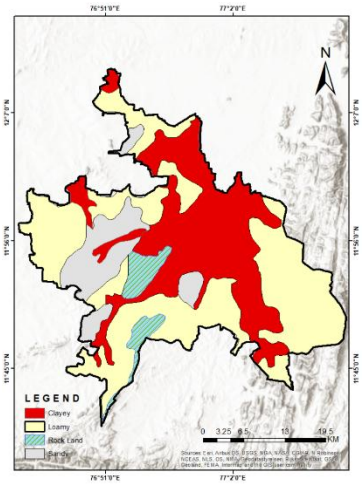

Figure 6: soil texture map

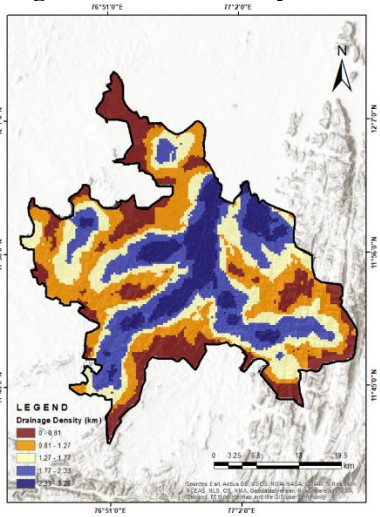

Figure 7: Drainage density map

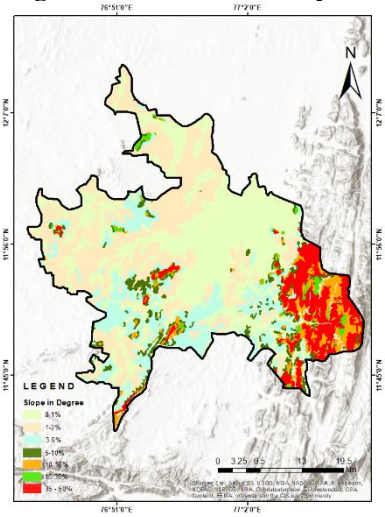

Figure 8: Slope map

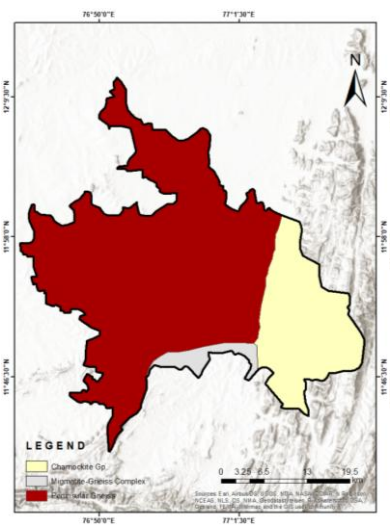

Figure 9: Geology map

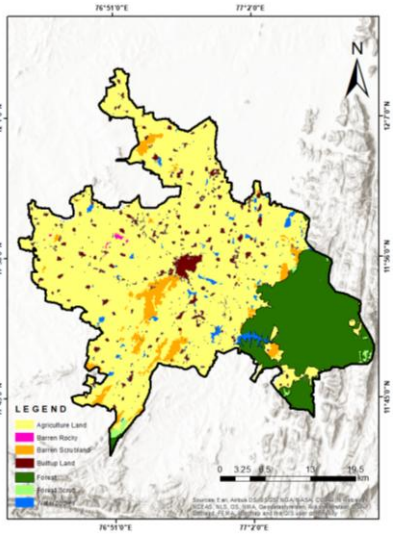

Figure 10: LULC map

3. Result and discussion:

3.1 Standardization of criteria maps:

Initially, the selected criteria maps are measured in different units. To utilize the Analytic Hierarchy Process (AHP) for land suitability assessment, it is necessary to standardize the criteria maps, ensuring they share a uniform scale. Standardization techniques transform the measurements within each criterion map into a consistent measurement scale, thereby removing their dimensional differences and measurement units (Reshmidevi et al., 2009). To achieve standardization, all criteria vector maps were converted into raster data formats. Subsequently, the raster maps were reclassified into three comparative categories: highly suitable, moderately suitable, and unsuitable using the Spatial Analyst tool in ArcMap, as previously discussed. Once standardization of all criteria maps is completed, the weights for each criteria map can be computed using AHP. Finally, the land suitability map was prepared with the help of the ArcGIS 10.7.1 platform.

3.2 Calculation of weight for criteria maps:

The analytic hierarchy process (AHP) is employed to determine the weights for the criteria maps. AHP is a methodical approach for dissecting complex decisions into pairwise comparisons (Taherdoost, n.d.). It entails breaking down substantial and abstract decision problems into smaller, more manageable sub-problems suitable for pairwise evaluation(Taherdoost, n.d.). A specialized AHP plugin tool designed for the ArcGIS environment was utilized to compute weights for the various criteria layers. By utilizing pairwise comparison matrices, the AHP calculates relative weights for individual criterion layers. Additionally, it generates a consistency ratio (CR), serving as an indicator of the logical consistency of expert or user judgments during pairwise criteria comparisons, as quantified by Eq. (1).

$$\mathrm{CR} = \frac{CI}{RI}$$

The CR measurement is instrumental in pinpointing potential errors by gauging the Consistency Index (CI) against the Random Index (RI). The accuracy of judgments hinges on these values. According to Taherdoost, n.d., if the CR value significantly surpasses 0.1, judgments made through pairwise comparisons are considered unreliable due to their proximity to randomness. (Taherdoost, n.d.) established a 'fundamental scale' for constructing pairwise comparison matrices within AHP, as outlined in Table 3. This procedure entails creating a matrix where each criterion is systematically compared with others based on their relative importance, using a scale ranging from 1 to 9. A rating of 1 signifies equal preference between a pair of criteria layers, while 9 denotes a substantial preference for one criterion layer over another, as determined by expert judgment (Taherdoost, n.d.).

Once the relative importance of each criterion layer is established through pairwise comparisons, these values are input into an ArcGIS-based Analytic Hierarchy Process (AHP) tool to generate corresponding

weights and CR values. Table 3 presents the pairwise comparison inputs necessary for the AHP to compute weights for the criteria layers. The resulting weights, derived from the AHP procedure using the inputs in Table 4, range from 0 to 1, where 0 represents the least important and 1 signifies the most important criteria for determining land suitability. Table 6 displays various indices generated by the GIS-based AHP tool, with the consistency ratio (CR) value being determined by the CI and RI according to Equation 3.

Table 2: The fundamental scale for pair-wise comparison matrix (Taherdoost, n.d.)

Relative importance	Defination	Description
1	Equally important	Two criteria are equally enriching to the objective
3	Slightly important	Judgments and experience slightly favour one criteria over another
5	Fundamentally important	Judgments and experience strongly favour one over the other
7	Really important	One is strongly favoured and its dominance is established in practice
9	Absolutely important	Evidence favouring one criteria over another is of the highest probable order of affirmation
2,4,6,8	Adjacent	Used when intermediate importance is needed

Table 3: Pair-wise comparison matrix for multi-criteria decision aspects

Parameters	Slope	Relief	Soil texture	Rainfall	Geology	Geomorphology	DD	LULC
Slope	1	4	4	5	3	5	5	9
Relief	0.25	1	1	2	3	2	3	3
Soil texture	0.25	1	1	4	4	6	5	6
Rainfall	0.2	0.5	0.25	1	1	2	4	6
Geology	0.33	0.33	0.25	1	1	4	4	5
Geomorphology	0.2	0.5	0.17	0.5	0.25	1	3	4
DD	0.2	0.33	0.2	0.25	0.25	0.33	1	3
LULC	0.11	0.33	0.17	0.17	0.2	0.25	0.33	1

Table 4: normalized pairwise comparison matrix

	Slope	Relief	Soil texture	Rainfall	Geology	Geomor phology	DD	LULC	Normalized weight
Slope	0.3937	0.5006	0.5682	0.3592	0.2362	0.2430	0.1974	0.2432	0.3427
Relief	0.0984	0.1252	0.1420	0.1437	0.2362	0.0972	0.1184	0.0811	0.1303
Soil texture	0.0984	0.1252	0.1420	0.2874	0.3150	0.2915	0.1974	0.1622	0.2024
Rainfall	0.0787	0.0626	0.0355	0.0718	0.0787	0.0972	0.1579	0.1622	0.0931
Geology	0.1299	0.0413	0.0355	0.0718	0.0787	0.1944	0.1579	0.1351	0.1056
Geomorphology	0.0787	0.0626	0.0241	0.0359	0.0197	0.0486	0.1184	0.1081	0.0620
DD	0.0787	0.0413	0.0284	0.0180	0.0197	0.0160	0.0395	0.0811	0.0403
LULC	0.0433	0.0413	0.0241	0.0122	0.0157	0.0121	0.0130	0.0270	0.0236

Table 5: random index table

N	1	2	3	4	5	6	7	8	9	10
R1	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49

Table 6: weights and CR of all criteria

Parameters	Sub criteria	normalized weight	C R
Geomorphology	Highly dissected hills & Valley	0.283177	0.62
	Low dissected hills & valley	0.173254	
	Moderate dissected hills & valley	0.264362	
	Moderately dissected plateau	0.123811	
	Pediment pediplain complex	0.100623	
	Quarry & mine dump	0.054773	
Geology	Charnockite	0.443062	0.19
	Migmatite	0.387506	
	Peninsular gneiss	0.169433	
Soil texture	Loamy	0.562054	0.23
	Clayey	0.221509	
	Sandy	0.149895	
	Rockland	0.066542	
Relief	600 - 800	0.552301	0.19
	800 - 1000	0.283095	
	1000 - 1200	0.113116	
	>1200	0.051489	
Rainfall	600 (mm)	0.333528	0.35
	800 (mm)	0.350195	
	1000 (mm)	0.173203	
	1200 (mm)	0.064137	
	>1200 (mm)	0.078936	
Slope	0 - 1 (Nearly Level)	0.265165	0.61
	1 - 3 (Very Gentle Slope)	0.249195	
	3 - 5 (Gentle Slope)	0.245218	
	5 - 10 (Moderate slope)	0.099219	
	10 - 15 (strong slope)	0.073965	
	15 - 35 (Moderate steep slope)	0.040545	
	35 - 50 (Very steep slope)	0.026693	
DD	0 - 0.8	0.363915	0.58
	0.8 - 1.27	0.258125	
	1.27 - 1.77	0.180602	
	1.77 - 2.33	0.133449	
	2.33 - 3.28	0.063909	
LULC	Agriculture Land	0.444172	0.54
	Barren rocky	0.145046	
	Barren scrubland	0.110649	
	Forest	0.146875	
	Forest scrub	0.067274	
	Waterbodies	0.085984	

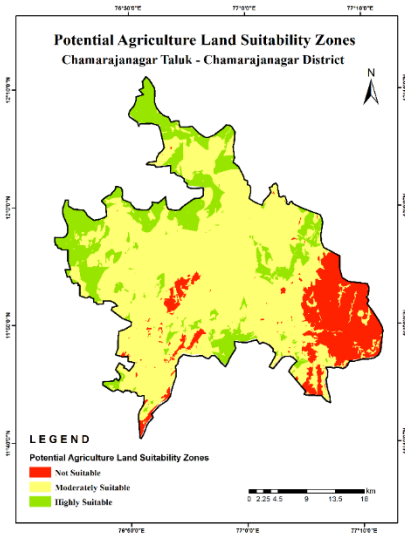

Figure 11: Agriculture land suitability map

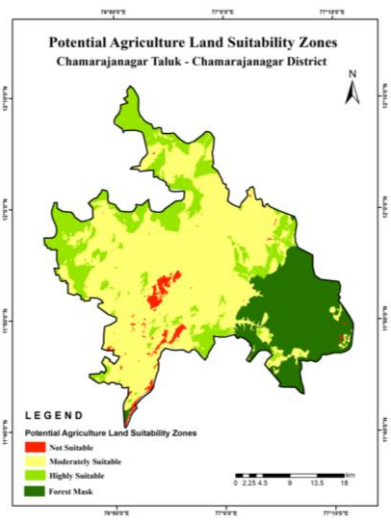

Figure 12: Agriculture land suitability forest mask

4. Conclusion:

Determining the optimal land use to maximize its potential and mitigate resource depletion resulting from population growth is essential for sustainable development. This study employed a comprehensive approach integrating GIS (Geographic Information Systems) and AHP (Analytic Hierarchy Process) to assess the suitability of agricultural land within the study area. Factors considered in the analysis encompassed physical dimension, totaling 8 criteria. These factors included relief, slope, drainage density, soil texture, rainfall, geomorphological and geological features, and land use and land cover. The AHP technique was utilized to determine the relative importance of each factor through weight calculation. The agricultural land suitability map was generated with the help of ArcGIS. According to the study result, the lands with very low slope, low relief, are the most suitable for agricultural production. While GIS provides enhanced flexibility and accuracy in land use planning, several researchers argue that integrating GIS with methodologies like AHP yields superior outcomes. In our study, we amalgamated AHP with GIS analyses to assign weights to criteria and sub-criteria, acknowledging their varying degrees of importance in land use determination. Our findings demonstrate that this integration enhances decision-making for policymakers and planners, enabling them to consider multiple criteria with distinct weights when formulating strategies, policies, or decisions regarding land use preservation or alteration. This combination of AHP with GIS represents a burgeoning trend in land use planning, affirming the potential for leveraging insights from prior research to inform and enrich land use planning endeavors.

5. References:

Akinci, H., Özalp, A. Y., & Turgut, B. (2013). Agricultural land use suitability analysis using GIS and AHP technique. *Computers and Electronics in Agriculture*, *97*, 71–82. https://doi.org/10.1016/j.compag.2013.07.006

Armanios, D. E., & Fisher, J. B. (2014). Measuring water availability with limited ground data: Assessing the feasibility of an entirely remote-sensing-based hydrologic budget of the Rufiji Basin, Tanzania, using TRMM, GRACE, MODIS, SRB, and AIRS. *Hydrological Processes*, *28*(3), 853–867. https://doi.org/10.1002/hyp.9611

Bagheri, M., Sulaiman, W. N. A., & Vaghefi, N. (2012). Land use suitability analysis using multi criteria decision analysis method for coastal management and planning: A case study of Malaysia. *Journal of Environmental Science and Technology*, *5*(5), 364–372. https://doi.org/10.3923/jest.2012.364.372

Cengiz, T., & Akbulak, C. (2009). Application of analytical hierarchy process and geographic information systems in land-use suitability evaluation: A case study of Dümrek village (Çanakkale, Turkey).

International Journal of Sustainable Development and World Ecology, *16*(4), 286–294. https://doi.org/10.1080/13504500903106634

Ennaji, W., Barakat, A., El Baghdadi, M., Oumenskou, H., Aadraoui, M., Karroum, L. A., & Hilali, A. (2018). GIS-based multi-criteria land suitability analysis for sustainable agriculture in the northeast area of Tadla plain (Morocco). *Journal of Earth System Science*, *127*(6). https://doi.org/10.1007/s12040-018-0980-x

Feizizadeh, B., Shadman Roodposhti, M., Jankowski, P., & Blaschke, T. (2014). A GIS-based extended fuzzy multi-criteria evaluation for landslide susceptibility mapping. *Computers and Geosciences*, *73*, 208–221. https://doi.org/10.1016/j.cageo.2014.08.001

Jafari, S., & Zaredar, N. (2010). Land Suitability Analysis using Multi Attribute Decision Making Approach. *International Journal of Environmental Science and Development*, 441–445. https://doi.org/10.7763/ijesd.2010.v1.85

Khan, R. M., & Ahmed, P. (2023). *Agricultural land use suitability analysis using GIS and AHP technique in Baramulla district of the Kashmir valley, India*. https://doi.org/10.21203/rs.3.rs-3080748/v1

Kumar Prajapati, R., Triptathi, S., & Mishra, R. M. (2015). Rajesh Kumar Prajapati. et al Page | 427 International Journal of Advanced Research in Science and Technology Geo-spatial Technology of Panna National Park (M.P.) India. In *Int. J. Adv. Res. Sci. Technol* (Vol. 4, Issue 6). www.glovis.usgs.gov,

Memarbashi, E., Azadi, H., Barati, A. A., Mohajeri, F., Passel, S. Van, & Witlox, F. (2017). Land-use suitability in Northeast Iran: Application of AHP-GIS hybrid model. *ISPRS International Journal of Geo-Information*, *6*(12). https://doi.org/10.3390/ijgi6120396

Mendas, A., & Delali, A. (2012). Integration of MultiCriteria Decision Analysis in GIS to develop land suitability for agriculture: Application to durum wheat cultivation in the region of Mleta in Algeria. *Computers and Electronics in Agriculture*, *83*, 117–126. https://doi.org/10.1016/j.compag.2012.02.003

Özkan, B., Dengiz, O., & Turan, İ. D. (2020). Site suitability analysis for potential agricultural land with spatial fuzzy multi-criteria decision analysis in regional scale under semi-arid terrestrial ecosystem. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-79105-4

Reshmidevi, T. V., Eldho, T. I., & Jana, R. (2009). A GIS-integrated fuzzy rule-based inference system for land suitability evaluation in agricultural watersheds. *Agricultural Systems*, *101*(1–2), 101–109. https://doi.org/10.1016/j.agsy.2009.04.001

Rondhi, M., Pratiwi, P. A., Handini, V. T., Sunartomo, A. F., & Budiman, S. A. (2018). Agricultural land conversion, land economic value, and sustainable agriculture: A case study in East Java, Indonesia. *Land*, *7*(4). https://doi.org/10.3390/land7040148

Taherdoost, H. (n.d.). *Decision Making Using the Analytic Hierarchy Process (AHP); A Step by Step Approach*. http://www.ahooraltd.comhttp://www.hamta.org

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